Nepalese Journal of Zoology

ISSN: 2705-4403 (Print) & 2705-4411 (Online)
www.cdztu.edu.np/njz

Volume 7 | Issue 2 | December 2023

https://doi.org/10.3126/njz.v7i2.60809

Research article

Chital's call: An appeal for conservation strategies in the forest of the Institute of Forestry, Hetauda, Nepal

Aayush Shrestha[1*] | Bijaya Dhami [2]

[1] Hetauda Campus, Institute of Forestry, Tribhuvan University, Nepal
[2] Department of Biological Sciences, University of Alberta, AB 116 St & 85 Ave, Edmonton, Canada
*** Correspondence:** aayush.shrestha69@gmail.com

Suggested citation: Shrestha A. and Dhami B. 2023. Chital's call: An appeal for conservation strategies in the forest of the Institute of Forestry, Hetauda, Nepal. Nepalese Journal of Zoology, 7(2):38–48. https://doi.org/10.3126/njz.v7i2.60809

Article History:
Received: 30 September 2023
Revised: 18 December 2023
Accepted: 18 December 2023

Abstract

The chital, *Axis axis*, constitutes one of Nepal's six deer species and maintains a closed population within the forest of the Institute of Forestry, Hetauda Campus. Presently, the chital population faces a range of challenges, prompting a comprehensive study encompassing population status, habitat preference analysis, and threat assessment. We utilized the pellet group count method on 74 systematic random sample plots (4×4m) within a 100×100 m grid for population estimation. Pellet presence/absence in predetermined habitat characteristics was analyzed to assess habitat preferences. Concurrently, a relative threat ranking method from household interviews was employed to evaluate existing threats. The study revealed a total chital population estimate of approximately 141 individuals, with a population density of 190 individuals per km^2. Their habitat preference showed an affinity towards areas abundant in Sal and riverine forests, along with an inclination towards locations further from roads within the forested areas. Primary threats to the chital population encompassed attacks from feral dogs, illegal hunting, and habitat degradation mainly due to invasive alien plant species. This study shows that with effective management of the feral dogs, mitigation strategy to control illegal hunting with the help of local authorities, and improving the habitat conditions concerning their preferences, the chital population has the potential to continue growing in the coming years.

Keywords: *Axis axis*; Population estimation; Pellet group count; Habitat preferences; Threats

1 | Introduction

A chital is an even-hoofed ungulate with either two or four hoofed toes on its front and back legs, with a reduction in the number of toes on the first and fifth digits compared to the five digits it originally possesses (Schaller 1998). The *Axis* genus comprises four species of spotted deer, with the Spotted deer or chital (*Axis axis*) being the most prevalent and largest among them (Kurt 1990). Within the *Axis axis* species, there are two recognised subspecies: *Axis axis axis*, which inhabits Nepal, India, and Sri Lanka, and *Axis axis ceylonensis*, found exclusively in Sri Lanka (Ellerman & Morrison-Scott 1964; Duckworth et al. 2015). It is classified as "Least Concern (LC)" by the IUCN, primarily due to its extensive distribution and substantial population sizes (Duckworth et al. 2015).

Chital has an extensive presence in the lowlands of Nepal and can be encountered in several protected areas as well as adjacent forests. Their habitats include scrublands, forests, and grasslands adjacent to cultivated areas, and the preferences vary depending on the seasonal changes (Mishra 1982). During the hot and dry period, they tend to inhabit riverine forests, while in the monsoon season, they prefer Sal forests (Ranjitsinh 1991). They are primarily found at elevations below 1000 m (Raman 2013). Although sightings of these deer above 1000 meters in their natural habitat are rare, they can occasionally be spotted in smaller numbers in mid-hill regions, warmer valleys, and wooded areas (Schaller 1967; Bhattarai et. al. 2012). Their diet predominantly includes fruits, browse, and grasses, and they tend to remain near water sources (Ranjitsinh 1991; Dinerstein 1982; Wegge et al. 2006). Despite consuming both grasses and browse, they exhibit a preference for green vegetation and cultivated crops such as mustard and wheat (Shaha & Richard 2001).

The chital population in Nepal is facing significant threats due to human encroachment, poaching, forest fires, forest fragmentation (Chalise 2013) and invasive plant species

Figure 1. Death of chital in the study area from feral dog attack (a) and from possible trap setting (b).

(Adhikari et al. 2022). Similar challenges are observed in the forest of the Institute of Forestry (IOF), Hetauda Campus, where attacks from feral dogs (Fig. 1a), illegal hunting, trap setting (Fig. 1b), and habitat degradation are becoming increasingly prevalent. The forest of IOF has historically supported closed populations of chital. Closed populations necessitate a comprehensive understanding of population size, habitat usage determinants, and existing conservation efforts. This knowledge is imperative for implementing effective management and conservation strategies (Khulal et al. 2021) Furthermore, the proper estimation of chital populations using methods like pellet group count through a well-designed sampling strategy is still unknown. This study aimed to estimate the population status of chital, their habitat preferences and their conservation threats in the forests of IOF so that appropriate measures can be taken to ensure their conservation in the forest of IOF.

2 | Materials and methods

2.1 | Study area

The study was conducted within the forest area of IOF, Hetauda Campus (Fig. 1). Hetauda is a sub-metropolitan

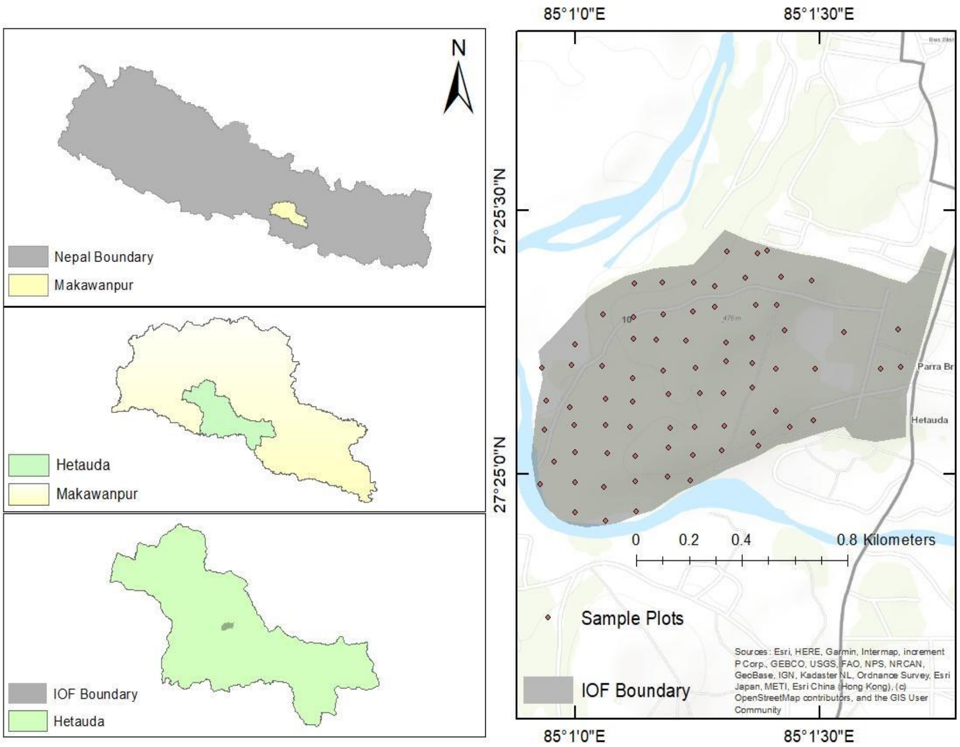

Figure 2. Map of the study area (Forests of IOF) showing the survey design

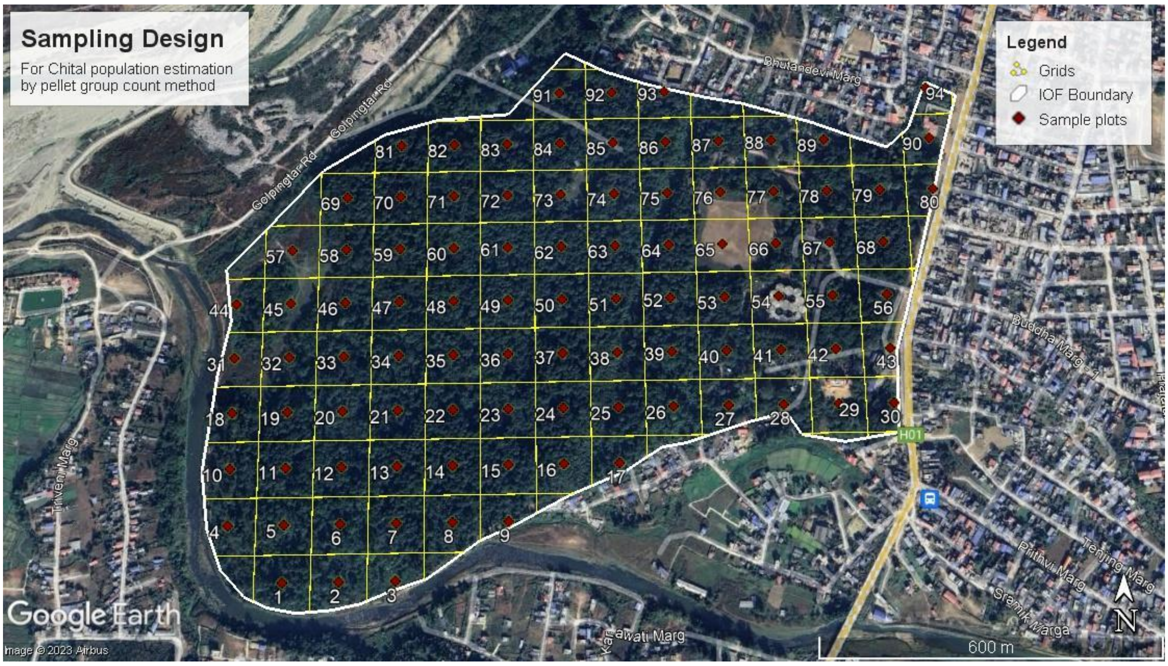

Figure 3. Sampling design for pellet group count method

city in the Makwanpur District of Bagmati Province in central Nepal. It lies at 27°25' N latitude and 85°02' E longitude and is situated at a level of 300-390m asl. The Hetauda sub-metropolitan city covers 261 km^2 where land covers 254 km^2. (97%) and water covers 7 km^2 (3%). Boundary- East: Bakaiya Rural Municipality, West: Manahari and Raksirang Rural Municipality, South: Parsa District and Bara District, North: Makwanpur Garhi, Bhimphedi and Kailash Rural Municipality. The city is surrounded by three rivers—the Rapti to the west, the Samari to the north, and the Karra to the south. IOF lies southwest of Hetauda and has an area of approximately 96 hectares. It contains vegetation typical of tropical and subtropical forests, providing a diverse habitat for a variety of plant and animal species, with riverine forest, mixed forest, grassland and seasonal wetland near a perennial river (Pokharel 2017). This includes over 150 types of plants (Singh 2016), 98 butterfly species (Chhetri 2017), and 91 bird species (Pokharel 2017). Based on our observation of direct and indirect signs, it also inhabits the faunal species such as Spotted Deer *Axis axis,* Rhesus Monkey *Macaca mulatta,* Indian Grey Mongoose *Herpestes edwardsii*, Masked Palm Civet *Paguma larvata*, Wild Boar *Sus scrofa*, five-striped palm squirrel *Funambulus pennantii* etc. The study area has a boundary of national highway in the east, Karra River in the south, human settlement in the north, and gravel road to the west.

2.2 | Data collection

The field survey was carried out during the dry season in early March 2023, a period when the signs of chital and other ungulates are more readily visible (Dhami et al. 2023a). This time frame also offers the advantage of thinner vegetation, streamlining the process of clearing selected plots for the pellet survey (Dhami et al. 2023b, c).

2.2.1 | Sampling design

The "fishnet" function of ArcGIS software 10.4.1 (ArcGIS E. S. R. I. 2020. Release 10.4. 1. *Redlands, CA: ESRI*.) was employed to divide the entire study area into 96 grids with a grid size of 1 hectare (Figure 4) to accommodate fine-scale habitat types. Plot-to-plot distance of 100 m was maintained with the motive of intensive sampling design. We selected a total of 74 grids as our study area, carefully excluding areas representing various amenities like playgrounds, classrooms, cafeterias, and other facilities at the Institute of Forestry, Hetauda Campus, using Google Earth imagery. Thus, selected grids were assigned with a plot size of 4×4 m^2 in the center point (Dhami et al. 2023b). The geographic coordinates of the points were extracted and loaded in a GPS device for navigation to the sampling locations.

2.2.2 | Pellet group count

The pellet group count method was employed to estimate the population size. This method has been widely used in previous studies to estimate the population size of ungulate species (Bennett et al. 1940; Eberhardt & Van Etten 1956; Krebs et al. 2001; Marques et al. 2001; Barnes 2002). This technique is relatively simple and cost-effective, and there exists a strong correlation between estimates derived from pellet-group counts and other methods (White 1992; Barnes 2001). Unlike distance sampling, pellet counts are suitable for a wide range of open and densely forested environments, especially in terms of detection probability (Franceschi et al. 2023). In open environments such as national forests, deer may flee at distances greater than observable, while in dense forests and tall grasslands of parks and reserves, the detection probability is extremely low. Here a more precise pellet counting method, known as the "clearance

Table 1. Scale of classification for scope, severity, and urgency of threats

Threat category	Scale	Classification	Definition
Scope	4	Very high	The threat that is probably going to influence the target over all or most (71–100) % of the populace.
	3	High	The threat that is probably going to influence the target over much (31–70) % of the populace.
	2	Medium	The threat that is probably going to influence the target over some (11–30) % of the populace.
	1	Low	The threat that is probably going to influence the target over a small proportion (1–10) % of the populace.
Severity	4	Very high	Within the scope, the threat is probably going to demolish, banish, or diminish the populace by 71–100% in the following 10 years
	3	High	Within the scope, the threat is probably going to seriously diminish the populace by 31–70% in the following 10 years
	2	Medium	Within the scope, the threat is probably going to moderately diminish the populace by 11–30% in the following 10 years
	1	Low	Within the scope, the threat is probably going to slightly diminish the populace by 1–10% in the following 10 years
Urgency	4	Very high	The impacts of the threat can't be overturned, it's impossible the target can be re-established and will take over 100 years to do it
	3	High	The impacts of the threat can be overturned and the target reestablished within 21–100 years
	2	Medium	The impacts of the threat can be overturned and the target reestablished within 6-100 years
	1	Low	The impacts of the threat are easily reversible and the target is reestablished within 0–5 years

plot" method is employed by clearing existing pellets and estimating deposition during subsequent visits as practiced by Shrestha (2004). The forest had no other herbivores other than the occasional grazing of goats from the nearby settlement areas. However, to eliminate the confusion in identifying pellets, we referred to Gurung et al. (1996).

Some predetermined sampling rules were assigned as practiced by Shrestha (2004) and Gupta (2007):

a) Ridge tops in sloppy terrain were generally avoided,
b) Pellet group consisted of ≥5 pellets spread out close together and have similar sizes, shapes, textures, and colors (Freddy & Bowden 1983), and
c) The best estimate of the number of pellet groups was made based on the age of pellets, color, sheen, and level of degradation.

2.2.3 | Habitat preferences

During the detailed field survey for pellet count, we also reported dominant habitat type, distance to the nearest road, settlements, water source, and presence/absence of invasive species. The dominant habitat type was determined virtually by looking at the species' dominance. For measuring the nearest distance from the center of the sample plots to the roads, rivers, and settlements, we used the “Distance” function in ArcGIS software. In the case of identifying the Invasive Alien Plant Species (IAPS), we referred to Shrestha and Shrestha (2021).

2.2.4 | Threat assessment

We interviewed 20 households (80% of the sample) within a 500m distance from the edge of the forest area using semi-structured questionnaires to ensure proximity to the study site, as residents within this range are likely to have a more intimate knowledge of the area and its conservation threats (Kandel et al. 2023). We conducted interviews in the local language, subsequently translating them into English. Our aim was to frame open-ended questions whenever feasible to capture the genuine sentiments of the respondents on various issues (Phuyal et al. 2023). These surveys aimed to identify and rank the various conservation threats in the study area. To rank these threats, we employed the relative threat ranking method, as described by WWF in 2007, followed by Kafle et al. (2020), Neupane et al. (2020), and Chhetri et al. (2020). The ranking of the threats was based on three criteria: scope, severity, and urgency which helped to understand and determine the most significant existing threats in the area.

2.3 | Data analysis

The chital population density was calculated by the formula:

$$\text{Population density/km}^2 = \frac{\text{Total pellet groups counted}}{\text{Pellet groups per day per chital} \times \text{Time interval between visits} \times \text{Total plot area in sq. km.}}$$

The population was calculated by multiplying the deer population density/km^2 by the sampling area taken in

Table 2. Estimates and statistics for the final model predicting the probability of observing chital

Predictor	Estimate	S.E	*χ2*	*p-value*
Intercept	-3.50	1.40		
Habitat type			8.43	0.03 *
Mixed forest	0			
Grassland	- 0.85	1.49		
Sal forest	1.93	1.21		
Riverine forest	1.32	1.20		
Road Distance	0.02	0.01	9.65	0.001 **

km^2. The time interval was kept at 20 days, the sampling area was 74 hectares (0.74 km^2), and the pellet group deposition per day per spotted deer is taken to be 24 as per Dinerstein (1980).

A binomial distribution model employing the logit link function was employed to analyze the factors influencing the presence of chital within the designated study area (Equation 1).

Equation 1: The logit link function is: $(\log(y/(1-y)))$

In this equation, the logit link function is represented as the natural logarithm of the odds ratio of the probability of chital presence (y) to its absence (1-y). The study's dependent variable was the binary presence or absence of chital at specific sampling locations, while the independent variables consisted of five predetermined habitat characteristics: Habitat type, nearest water distance, nearest settlement distance, nearest road distance, and the presence or absence of invasive species. Statistical analysis was conducted using the widely used open-source software tool: "R × 64 4.0.3 (http://cran.r-project.org/)" (R Core Team 2020) to identify the most influential factors affecting chital detectability in the study area. Initially, all habitat parameters were included in an initial model, and the data were assessed for over-dispersion. The summary table of the model indicated that the data did not exhibit overdispersion. The backward selection method, involving the stepwise removal of insignificant variables, was employed to establish the final model, including covariates for which the likelihood ratio test resulted in a significant p-value at a 5% significance level. To assess the adequacy of the model fit, binned residual plots were generated, following the criteria of homogeneity and independence (Fig. 5) as recommended by Gelman and Hill (2006). The binned residual plots were generated using the "binnedplot" function from the "arm" package, with default settings for bin calculation, as described by Gelman et al. (2018).

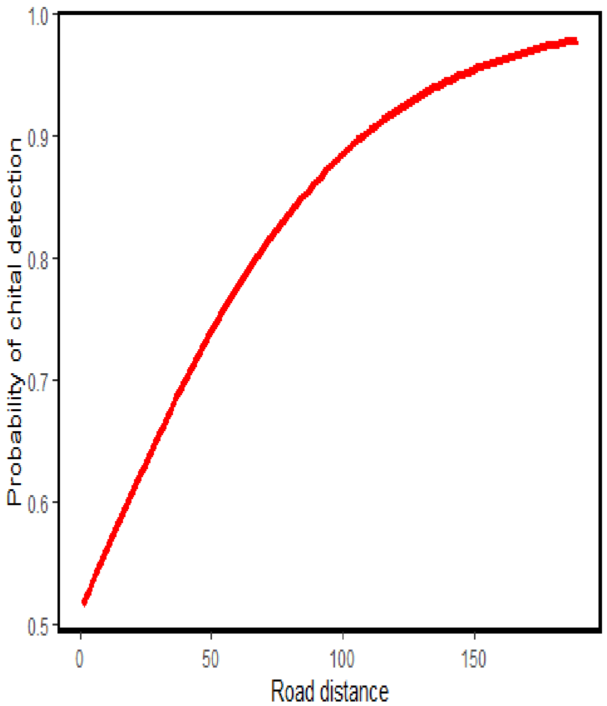

Figure 4. Figure showing the probability of chital detection in relation to road distance.

The threats identified during the site visit were assigned a relative rank from high (5) to low (1) based on the criterion of WWF (2007). Further, it was reclassified into five categories: very high, high, medium, low, and very low.

3 | Results

3.1 | Chital population and habitat use

The total chital population in IOF, Hetauda campus was estimated to be approximately 141 individuals with a density of 190/km^2.

Among the five habitat variables examined in this study, there were no significant differences in the probability of chital detection for the following three variables: Water Distance, Settlement Distance, and Presence/absence of invasive species. However, the "Habitat type" and Road distance (walking trail/ motor road) variables exhibited significant differences among the factors for the probability of detection. Therefore, the final model given by the binary logistic regression for the presence/absence of chital in a particular area is given below:

Probability of chital detection = -3.501444 - 0.852800×Grassland + 1.932841× Sal forest + 1.327636× Riverine forest + 0.028715×Road distance + error

The final binomial distribution model with logit link function with estimates and standard errors for each significant variable is presented in Table 2. Our final model showed that the probability of chital detection increases with an increase in Sal forest and Riverine forest as habitat types and an increase in Road distance (Fig. 4). Further, an examination of the binned residual plot (Fig. 5) revealed that the dispersion of residual averages is homogenous with no patterns.

3.2 | Threats to chital in the study area

From the relative threat ranking, we found that feral dogs are the most critical threat to the chital in the forest. Attacks from feral dogs were ranked as a very high threat,

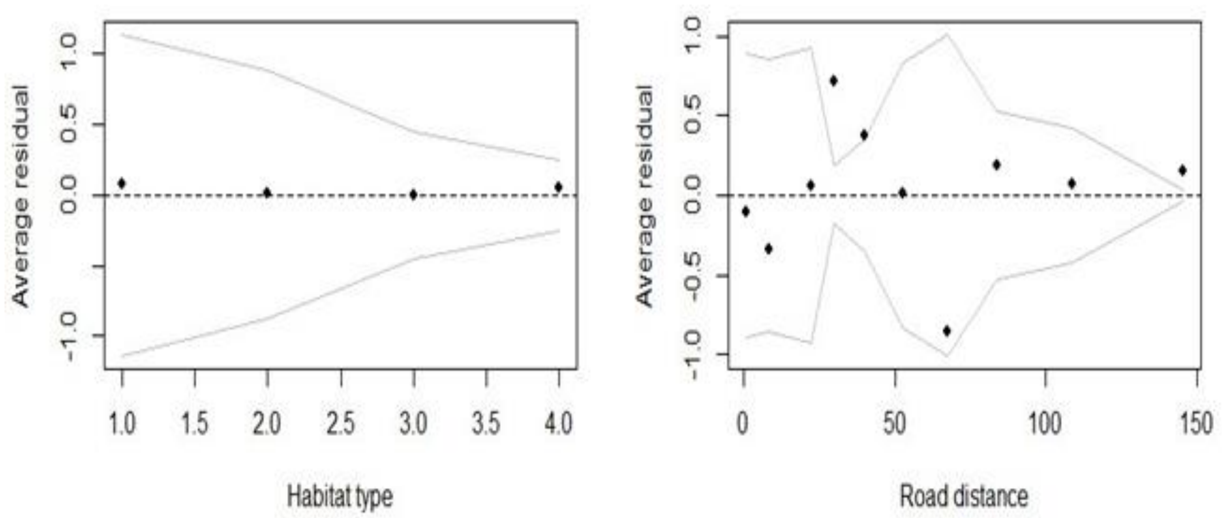

Figure 5. Binned residual plot of residual averages (calculated by the default bin-identification setting of binned plot function of package arm) vs. predicted values. The drawn lines are the limits of the 95% confidence intervals.

whereas, illegal hunting, habitat degradation, climate change, and human interventions i.e. collecting forest products were regarded as high, medium, low, and the lowest threat to chital respectively (Table 3).

4 | Discussion

The population of chital in the forests of IOF is estimated to be approximately 141 individuals, with a deer density of 190/km^2. This is notably higher than what was observed in the national prey base survey in protected areas and adjoining forests by DNPWC and DoFSC (2022), where the highest recorded chital density was 114.61/km^2, specifically in Shuklaphanta National Park (ShNP). Taking into consideration, unlike ShNP, the forests of IOF lack natural predators and other herbivores that directly compete with deer for resources. However, it's important to acknowledge that some studies have reported similar and even higher densities of chital. According to Raman et al. (1996), who conducted a line transect survey in Guindy National Park (GNP), found the deer density of 185.4/km^2 (±29.3/km^2, 95% confidence interval) in 1991, and 239.2/km^2 (±37.2/km^2, 95% confidence interval) in 1992 where there were also blackbuck present, which served as direct competitors to the chital. Similarly, Naess and Andersen (1993) also estimated the densities exceeding 200/km^2 in Bardiya National Park. Provided with the appropriate management of existing threats, it is possible to observe an increase in the deer population within the forests of IOF.

The estimation of population size can be said to be indifferent to a specific period regardless of the seasonal variations or choice of the month as previous research has indicated that the breeding season of deer can vary across the geographical range (Seidensticker 1976; Khanpara et al. 2007). In tropical areas like India and the lowlands of Nepal, there is no distinct mating season and breeding can take place throughout the year (Waring 1996; Khanpara et al. 2007). The peak breeding season can differ for the same species in different locations within their habitats, potentially influenced by regional distinctions in climate and vegetation (Krishnan 1972; Khanpara et al. 2007). However, a previous study by Bhusal et al. (2020) on the breeding patterns of chital in the forests of IOF revealed that the highest occurrence of fawning took place during December, January, and February, although fawning was observed throughout the year except in July and the peak breeding period was identified as May-June.

Our findings indicate that the likelihood of detecting chital is positively correlated with the presence of Sal and Riverine forests as habitat types during the dry season. This aligns with previous studies conducted in the lowland terai landscape, underscoring the significance of grasslands and dense Sal forests as crucial habitats for spotted deer (Seidensticker 1976; Lamichhane et al. 2020; Regmi et al. 2022). Moreover, chital is a habitat generalist and tends to thrive in open grasslands interspersed with

Table 3: Threat assessment of the spotted deer in the study area

Threats	Scope	Severity	Urgency	Total	Threat Classification
Illegal hunting	4	4	3	11	High
Feral dogs	5	5	5	15	Very high
Habitat degradation	2	3	4	9	Medium
Human interventions from forest product harvesting	1	1	1	3	Very low
Climate change	3	2	2	7	Low

forested areas for shelter (Dinerstein 1980). In the summer and rainy seasons, the grasslands have high-quality forage availability due to habitat management efforts (Adhikari et al. 2021). But in the dry season, when the grass becomes dry and unpalatable, chital moves to different forest patches, likely because there's not enough food in the grasslands (Dhami et al. 2023a). Herbivores, including chital, select habitats that maximize nutrient intake (Westoby 1974) and adjust their movement between different habitats to meet changing needs (Bell 1971; McNaughton 1987). This preference for forest habitats in the dry season is not unique to chital; other grassland-dependent herbivores in the Terai lowland, like the Swamp deer, also display similar behavior (Dhami et al. 2023a).

Road disturbance exerts a substantial influence on the presence of herbivorous species, as evidenced by studies conducted by Laurian et al. (2012) and Leblond et al. (2013). Our research indicates a reduction in chital occurrence in habitats near roads, potentially attributed to elevated human activity along these walking trails, particularly by university students. Interestingly, the behavior of ungulates in relation to linear features varies under different ecological conditions (Neupane et al. 2021). However, in western Canada, white-tailed deer (*Odocoileus virginianus*) exhibit a strong preference for linear features like roads and trails, even though this may potentially increase their risk of encountering wolves (Darlington et al. 2022). This behavior is attributed to the fact that linear features can entice deer with abundant forage opportunities in heavily exploited landscapes.

This study finds that the attacks from feral dogs are the greatest threat to the chital population followed by illegal hunting, habitat degradation, climate change, and human interventions i.e. collecting forest products. The people residing around the forest, students, teaching, and non-teaching staff have also witnessed cases of feral dog attacks on chital especially targeting fawns and sub-adults.

In the absence of natural predators within the forests, feral dogs have emerged as potential predators (Figure 1a). Specifically, in habitats where prey density is high and feral dogs employ a pack hunting strategy, predation rates escalate (Duarte et al. 2016). Younger deer, such as fawns and yearlings, are particularly vulnerable targets for feral dogs due to their relative ease of capture. The dogs' approach involves harassing, chasing, and diverting the young from their mothers before preying upon them (Muro et al. 2011). Similar instances of depredation by feral dogs on Mediterranean deer have been documented in southern Spain (Duarte et al. 2016).

Feral dogs contribute to the spread of diseases, engage in wildlife harassment and predation, and compete with endemic species. Their role as carriers of transmissible pathogens i.e. 40 zoonotic diseases (Bergman et al. 2009), including rabies, parvovirus, and canine distemper virus (CDV), poses a significant threat to native and often endangered wildlife, leading to notable population declines (Woodroffe 1999). A notable example is the transmission of CDV from dogs to threatened Lake Baikal seals (*Phoca sibirica*), resulting in further declines in seal populations (Mamaev et al. 1995).

While the direct killing of wildlife is conspicuous, feral dogs also engage in harassing and chasing endemic species, inducing elevated stress and energetically costly behaviors in native wildlife (Lenth et al. 2008). The mere presence of dogs in an area can deter wildlife use and habitation, with detrimental effects on the breeding success of native species such as ungulates (Gingold et al. 2009). Gingold and colleagues (2009) observed that in the presence of dogs, no mountain gazelle (*Gazella gazella*) fawns survived after six months, indicating the occurrence of dog predation. In some instances, the impacts of dog predation may surpass those of wild predators. A study in the French Pyrenees by Bouvier and Arthur (1995) reported 733 kills of domestic sheep, with 91% attributed to feral dogs and the remaining 9% to brown bears (*Ursus arctos*). While the direct applicability of these results to wildlife species remains uncertain, it raises the prospect of elevated predation rates by dogs, particularly in proximity to human settlements.

This study finds poaching as another serious threat to the chital population considering some recent sightings of some traps inside the IOF perimeter (Figure 1b). Nepal continues to combat the ongoing issue of illegal wildlife trade, necessitating a comprehensive and multi-dimensional approach (Brown and Davies 2014). Such illegal activities have been recorded in many places including the dry Churiya hills of Far-Western Nepal (Neupane et al. 2010), the Nepali-Chinese and Nepali-Indian Border (Puri et al. 2020), Ghodaghodi Lake Complex (Lamsal et al. 2014), etc. endangering its biodiversity. It can have detrimental effects on animal populations, leading to potential local extinctions, decreased genetic diversity, diminished trophy sizes, hunting prospects, and shifts in sex ratios and age distributions (Coltman et al. 2003). Thus, the concerned authority should practice proper control methods to stop such illegal activities.

The effects of IAPS on the degradation of chital habitat are seen to be another threat to the existence of their population. A total of 22 species of IAPS are recorded in the forests of IOF where *Mikania micrantha*, *Chromolaena odorata*, *Lantana camara*, and *Ageratina houstonianum* are found mostly (Pandey et al. 2021) which is a worrying issue considering its small area. It threatens their survival and population growth mainly due to habitat loss and lack of palatable plant species by the IAPS invasion (Murphy et al. 2013) and are negatively associated with the abundance of wild ungulates (Adhikari et al. 2022). The other threats include impacts from climate change and human interference from forest product collection but these were not regarded as serious as above.

5 | Conclusions

Our study concludes that the total chital population inside the forests of IOF is approximately 141 with a population density of 190/ km^2 taking into note the forests have no natural predators and other direct competitors for food. Our study also demonstrated that the detectability of chital increases with the availability of Sal Forest and riverine forest habitat types. Furthermore, the detectability of chital also increases with an increase in road distance. The primary threats to the chital population include feral dog attacks, poaching, and habitat degradation mainly by the effects of IAPS. Therefore, we strongly recommend the habitat management interventions that influence the habitat preferences of chital, including the removal of feral dogs, strategic measures to combat illegal hunting by collaboration of local authorities i.e. Campus authority, Hetauda Sub-Metropolitan City and Forest office. Additionally, the management of IAPS for continued growth and long-term survival of chital population in the IOF forests is recommended.

Acknowledgements

We thank Mr. Raj Babu Pahadi for support during the household interview. We appreciate the support from Hari Prasad Adhikari, Biraj Chaudhary, Manoj Awasthi, Bibash Chaudhary, Lalita Joshi, Anishka Sah and all the participants from Tribhuvan University (TU), Institute of Forestry (IOF), Hetauda and Agriculture and Forestry University (AFU), Hetauda during the fieldwork.

Authors' contributions

A.S. conceptualized the study and collected and curated data. Both authors drafted the manuscript and finalized it.

Conflicts of interest

The authors declare no conflict of interest.

References

Abrahamian F.M. 2000. Dog bites: Bacteriology, management, and prevention. Current Infectious Disease, 2:446–453. https://doi.org/10.1007/s11908-000-0075-z

Adhikari J.N., Bhattarai B.P. and Thapa, T.B. 2021. Determinants of abundance and habitat association of mammals in Barandabhar Corridor Forest, Chitwan, Nepal. Folia Oecologica, 48(1):100–109.

Adhikari J.N., Bhattarai B.P., Rokaya M.B. and Thapa T.B. 2022. Distribution of invasive plants and their association with wild ungulates in Barandabhar Corridor Forest, Nepal. Folia Oecologica, 49(2):182–191.

Allendorf F.W., Seeb J.E., Knudsen K.L., Thorgaard G.H. and Leary R.F. 1986. Gene-centromere mapping of 25 loci in rainbow trout. Journal of Heredity, 77(5):307-312.https://doi.org/10.1093/oxfordjournals.jhered.a110247

Bagchi S.P., Goyal S.P. and Sankar K. 2008. Social organization and population structure of ungulates in a dry tropical forest in Western India (Mammalia, Artiodactyla). Mammalia, 17(1):44–49. https://doi.org/10.1515/MAMM.2008.008

Bailey R.E. and Putnam R.J. 1981. Estimation of fallow deer *Dama dama* populations from fecal accumulations. Journal of Applied Ecology, 18:697–702. https://doi.org/10.2307/2402361

Barnes R.F.W. 2001. How reliable are dung counts for estimating elephant numbers? African Journal of Ecology, 39(1):1–9 https://doi.org/10.1111/j.1365-2028.2001.00266.x

Bell R.H.V. 1971. A Grazing Ecosystem in the Serengeti. Scientific American, 225(1):86–93. http://www.jstor.org/stable/24922780.

Bennet L.J, English P.F. and McCain R. 1940. A study of deer populations by use of pellet-group counts. https://doi.org/10.2307/3796010

Bergman D.L., Breck S.W. and Bender S.C. 2009. Dogs gone wild: Feral dog damage in the United States. In: Boulanger, J. (Ed.), The Thirteenth Wildlife Damage Management Conference (177-183). Saratoga Springs, NY: Thirteenth WDM Conference.

Bhattarai B.P. and Kindlmann P. 2012. Habitat heterogeneity as the key determinant of the abundance and habitat preference of prey species of tiger in the Chitwan National Park, Nepal. Acta Theriologica, 57:89–97.

Bhusal A., Neupane B., Bhattarai S., Kapali A., Bhatta S. and Bajagain S. 2020. Breeding seasonality of chital (*Axis axis*) in the Hetauda Valley of Nepal. Journal of Institute of Forestry, Nepal, 17:174 –183. https://doi.org/10.3126/forestry.v17i0.33634

Bouvier M., Arthur C.P., Bourliere F., Barre V., Camerra, J.J., Herrenschmidt, V. et al. 1995. Protection et indemnisation des degats d'ours aux troupeaux domestiques dans les Pyrenees occidentales: Fonctionnement, importance economique et role dans la protection de l'ours. Proceedings on the Management and Restoration of Small and Relictual Bear Populations. Museum of Natural History, pp 510–521.

Brown P. and Davies B. 2014 Trading to extinction. Dewi Lewis Publishing, Wales

Butler J.R. A., du Toit J.T. and Bingham J. 2004. Free-ranging domestic dogs *Canis familiaris* as predators and prey in rural Zimbabwe: threats of competition and disease to large wild carnivores. Biological Conservation, 115(3):369–378. https://doi.org/10.1016/S0006-3207(03)00152-6

Chalise M.K. 2013. Nepalka Mirgaharu (in Vernacular Nepali), Revoscience, Vol III, Nov-May, pp 19–20.

Chaungyalpa D. 1998. A report on the monitoring of wildlife trade in Nepal: a case study of the wildlife watch group. WWF Nepal program.

Chhetri S. 2017. Status and Distribution of Butterfly "A case study from Institute of Forestry, Hetauda. B.Sc. Project Paper, Tribhuvan University, Nepal.

Chhetri N.B., Dhami B., Neupane B., Sadadev B.M. and Thapa N. 2020. Distributional evidence and threats to cheer pheasant *Catreus wallichii* in Annapurna Conservation Area, Nepal. Nepalese Journal of Zoology, 4(2):140–146. https://doi.org/10.3126/njz.v4i2.33906

Collins W.B. and Urness P.J. 1981. Habitat preference of mule deer as rated by pellet group distribution. Journal of Wildlife Management, 45:969–972. https://doi.org/10.2307/3808105

Collins W.B. and Urness P.J. 1984. The pellet group census techniques as an indicator of relative habitat use: respond to Leopold et al. Wildlife Society Bulletin, 12:327.

Coltman D.W., O'donoghue J.T., Jorgenson J.T., Hogg C., Strobeck and M. Festa-bianchet. 2003. Undesirable evolutionary consequences of trophy hunting. Nature, 426:655–658. https://doi.org/10.1038/nature02177

Corbett L.K. 1995. The Dingo: in Australia and Asia Sydney: University of New South Wales Press.

http://hdl.handle.net/102.100.100/231235?index=1

Darlington S., Ladle A., Burton A.C., Volpe J.P. and Fisher J.T. 2022. Cumulative effects of human footprint, natural features, and predation risk best predict seasonal resource selection by white-tailed deer. Scientific Reports, 12(1):1072. https://doi.org/10.1038/s41598-022-05018-z

Darwin C. 1868. The variation of animals and plants under domestication, 2 volumes. London, John Murray.

Darwin C. 1876. The Effects of Cross and Self-Fertilization in the Vegetable Kingdom. John Murray, London.

Daszak P., Cunningham A.A. and Hyatt A.D. 2000. Emerging infectious diseases of wildlife--threats to biodiversity and human health. science, 287(5452):443–449. doi/abs/10.1126/science.287.5452.443

Dhami B., Bhusal A., Neupane B., Nishan K.C., Lamichhane S., Bhattarai D. et al. 2023a. Fine-scale habitat characteristics influence the winter habitat use of swamp deer *Rucervus duvaucelii* in Shuklaphanta National Park, Nepal. Global Ecology and Conservation, e02648. https://doi.org/10.1016/j.gecco.2023.e02648

Dhami B., Neupane B., Devkota B.P., Maraseni T., Sadadev B.M., Bista S. et al. 2023b. Factors affecting the occupancy of Chinese pangolins *Manis pentadactyla* suggest a highly specialized ecological niche. Ecosphere, 14(1):e4356. https://doi.org/10.1002/ecs2.4356

Dhami B., Neupane B., Nishan K.C., Maraseni T., Basyal C.R., Joshi L.R. et al. 2023c. Ecological factors associated with hispid hare *Caprolagus hispidus* habitat use and conservation threats in the Terai Arc Landscape of Nepal. Global Ecology and Conservation, 43:e02437. https://doi.org/10.1016/j.gecco.2023.e02437

Dinerstein E. 1980. An ecological survey of the Royal Karnali-Bardia Wildlife Reserve, Nepal. Part III. Ungulate populations. Biological Conservation,18:5–38.

De R.C. and Spillet J.J. 1966. A study of chital or Spotted Deer in Corbett National Park, U. P. Journal of Bombay Natural History Society, 63(3):576–598.

DNPWC and DFSC. 2022. Status of Tigers and Prey in Nepal 2022. Department of National Parks and Wildlife Conservation and Department of Forests and Soil Conservation. Ministry of Forests and Environment, Kathmandu, Nepal

Duarte J., García F.J., and Fa J.E. 2016. Depredatory impact of free-roaming domestic dogs on Mediterranean deer in southern Spain: implications for human-wolf conflict. Folia Zoologica, 65(2):135–141. https://doi.org/10.25225/fozo.v65.i2.a8.2016

Duckworth J.W., Kumar N.S., Anwarul Islam M., Sagar Baral H. and Timmins R. 2015. *Axis axis*. The IUCN Red List of Threatened Species 2015: e.T41783A22158006. https://dx.doi.org/10.2305/IUCN.UK.2015.RLTS.T41783A22158006.en

Eberhardt L.L. and Van Etten R.C. 1956. Evaluation of the pellet group count as a deer census method. Journal of Wildlife Management, 20:70–74. https://doi.org/10.2307/3797250

Edge W.D. and C.L. Marcum 1989. Determining elk distribution with pellet group and telemetry techniques. Journal of Wildlife Management, 53:621–624. https://doi.org/10.2307/3809186

Ellerman J. and Morrison–Scott T. 1966. Checklist of Palaeartic and Indian mammals, second edition, Aldex, Oxford, pp 810

Franceschi S., Bongi P., Del Frate M., Fattorini L. and Apollonio M. 2023. A sampling strategy for habitat selection, mapping, and abundance estimation of deer by pellet counts. Journal of Wildlife Management, 87:e22345. https://doi.org/10.1002/jwmg.22345

Freddy D.J. and Bowden D.C. 1983. Sampling mule deer pellet group densities in Juniper-Pinyon woodland. Journal of Wildlife Management, 47:476–485. https://doi.org/10.2307/3808520

Fuller T.K. 1991. Do pellet count index white-tailed deer numbers and populations change? Journal of Wildlife Management, 55:393–396. https://doi.org/10.2307/3808966

Gelman A. and Hill J. 2006. Data analysis using regression and multilevel/hierarchical models. Cambridge university press.

Gelman R. and Greeno J.G. 2018. On The Nature of Competence: Principles for Understanding in a Domain©. In Knowing, learning, and instruction, Routledge, pp 125–186.

Gingold G., Yom-Tov Y., Kronfeld-Schor N. and Geffen E. 2009. Effect of guard dogs on behavior and reproduction of gazelles in cattle enclosures on the Golan Heights. Animal Conservation, 12: 155–162.

Gupta P.L. 2007. Study of Habitat and Population Status of Spotted Deer *Axis Axis*, Erxleben in Chitwan National Park (Doctoral dissertation, Department of Zoology). https://elibrary.tucl.edu.np/handle/123456789/8846

Gurung K. and Singh. R. 1996. Field Guide to the Mammals of the Indian Subcontinent.

https://lccn.loc.gov/98086250

Jathanna D., Karanatha K.V. and Johnsingh A.J.T. 2003. Estimation of large Herbivore density in the Tropical forest of Southern India using distance sampling. Journal of Zoology, 261(3): 285–290

Kurt F. 1990. Grzimek's Encyclopedia of mammals, Vol.5 Mc. Graw-Hill Publishing Company, New York.

https://doi.org/10.1017/S0952836903004278

Kafle K., Thanet D.R., Poudel P., Gautam D., Thapa G. and Bhatt P. 2020. Status and conservation threats to large mammals of the Laljhadi Mohana Biological Corridor, Nepal. Journal of Animal Diversity, 2(2):16–33. http://dx.doi.org/10.29252/JAD.2020.2.2.3

Kandel S.R., Neupane B., Miya M.S., Sadadev B.M., Khatri N.D. and Dhami B. 2023. An Emerging Issue of Human-Leopard Conflict in the Human-Dominated Landscape of Mid-Hills: A Case Study from Tanahun District of Nepal. International Journal of Zoology, 2023.

Khanpara P.S., Vachhrajani K.D., Gupta V.K., and Verma A. 2007. Time budget activity pattern of behavioral displays of captive axis deer *Axis axis.* Perspectives in animal ecology and reproduction (VK Gupta and A. Verma, eds.). Daya Publishing House, New Delhi, India. Pp 233–250.

Khulal R., Neupane B., Dhami B., Regmi S., Tiwari G. P. and Parajuli M. (2021). Habitat use and conservation threats to wild water buffalo *Bubalus arnee* (mammalia: Artiodactyla: bovidae) in Koshi Tappu wildlife reserve, Nepal. Journal of Threatened Taxa, 13(12):19714–19724.

Krebs C.J., R. Boonstra, V. Nams, M. O'Donoghue, K.E. Hodges and S. Boutin. 2001. Estimating snowshoe hare population density from pellet plots: a further evaluation. Canadian Journal of Zoology, 79:1–4. https://doi.org/10.1139/z00-177

Krishnan M. 1972. An ecological survey of larger mammals of peninsular India. Journal of the Bombay Natural History Society, 69:469–501. http://pascal-francis.inist.fr/vibad/index.php?action=getRecordDetail&idt=PASCAL7336016294

Kurt F. 1990. Grzimek's Encyclopedia of mammals, Vol.5, McGraw- Hill Publishing Company, New York.

Lamichhane S., Khanal G., Karki J.B., Aryal C. and Acharya S. 2020. Natural and anthropogenic correlates of habitat use by wild ungulates in Shuklaphanta National Park, Nepal. Global Ecology and Conservation, 24:e01338. https://doi.org/10.1016/j.gecco.2020.e01338

Lamsal P., Pant K.P., Kumar L. and Atreya K. 2014. Diversity, uses, and threats in the Ghodaghodi Lake complex, a Ramsar site in western lowland Nepal. International Scholarly Research Notices. http://dx.doi.org/10.1155/2014/680102

Laurian C., Dussault C., Ouellet J.P., Courtois R. and Poulin M. 2012. Interactions between a large herbivore and a road network. Ecoscience, 19(1):69–79. doi/abs/10.2980/19-1-3461

Leblond M., Dussault C. and Ouellet J.P. 2013. Avoidance of roads by large herbivores and its relation to disturbance intensity. Journal of Zoology, 289(1):32–40. https://doi.org/10.1111/j.1469-7998.2012.00959.x

Lenth B, Knight R. and Brennan M.E. 2008. The effects of dogs on wildlife communities. Natural Areas Journal, 28:218–227.

Mamaev L.V., et al. 1995. Characterization of morbilliviruses isolated from Lake Baikal seals *Phoca sibirica*. Veterinary Microbiology 44:251–259.

Marques F.F.C., Buckland S.T., Goffin D., Dixon C.E., Borchers D.L., Mayle B.A. et al. 2001. 'Estimating deer abundance from line transect surveys of dung: sika deer in southern Scotland', Journal of Applied Ecology, 38(2):349–63. http://www.jstor.org/stable/2655803

McNaughton S.J. 1987. Adaptation of herbivores to seasonal changes in nutrient supply. Nutrition of Herbivores edited by J.B. Hacker and J.H. Ternouth.

Mishra H.R. 1982. The Ecology and Behaviour of chital *Axis axis* in the RCNP, Nepal. PhD Thesis, University of Edinburgh. http://hdl.handle.net/1842/15405

Muro C., Escobedo R., Spector L. and Coppinger R.P. 2011. Wolf-pack *Canis lupus* hunting strategies emerge from simple rules in computational simulations. Behavioral Processes, 88(3):192–197. https://doi.org/10.1016/j.beproc.2011.09.006

Murphy S.T., Subedi N., Jnawali S.R., Lamichhane B.R., Upadhyay G.P., Kock R. et al. 2013. Invasive Mikania in Chitwan National Park, Nepal: the threat to the Greater One-horned Rhino Rhinoceros unicornis and factors driving the invasion. Oryx, 47(3):361–368. https://doi.org/10.1017/s003060531200124x

Naess K.M. and Andersen H.J. 1993. Assessing census Technique for Wild Ungulates in RBNP, Nepal. MSc Thesis, The Agricultural University of Norway, Norway.

Neupane P.K., Khadka M., Adhikari R. and Bhuju D.R. 2010. Lake water quality and surrounding vegetation in Dry Churiya Hills, Far-Western Nepal. Nepal Journal of Science and Technology, 11:181–188. doi=8523165ac6b5d88f89cedd57ffdd7- efe7513a9f3

Neupane B., Singh B.K., Poudel P., Panthi S., and Khatri, N.D. 2020. Habitat occupancy and threat assessment of gharial *Gavialis gangeticus* in the Rapti River, Nepal. Global Ecology and Conservation, 24:e01270. https://doi.org/10.1016/j.gecco.2020.e01270

Neupane B., Chhetri N.B. and Dhami B. 2021. Habitat selection of Himalayan Musk Deer *Moschus leucogaster* (Mammalia: Artiodactyla: Moschidae) with respect to biophysical attributes in Annapurna Conservation Area of Nepal. Journal of Threatened Taxa, 13(7):18703–18712.

Pandey K., Paudel G., Neupane A., Acharya K.R. and Adhikari S. 2021. Status of invasive alien plant species in Urban Forest of Hetauda, Nepal. Journal of Institute of Forestry, Nepal, 107. https://doi.org/10.3126/forestry.v18i01.41764

Phuyal N., Sadadev B.M., Khulal R., Bhatt R., Bajagain S., Raut N. et al. (2023). Assessing illegal trade networks of two species of pangolins through a questionnaire survey in Nepal. Journal of Threatened Taxa, 15(1):22381–22391.

Plumptre A.J. and S. Harris, 1995. Estimating the biomass of large mammalian herbivores in tropical montane forests: a method of fecal counting that avoids assuming a 'steady state' system. Journal of Applied Ecology, 32(1):111–120. https://doi.org/10.2307/2404420

Pokharel S. 2017. Diversity and habitat association of avifauna in and around IOF Complex, Hetauda, Nepal. B.Sc. Project Paper, Tribhuvan University, Nepal.

Puri G., Timilsina Y.P., Huettmann F., Regmi G.R. and Lama R.P. 2020. Poaching and Illegal Trade of Wildlife: What Do the Media Say for the Nepali-Chinese and Nepali-Indian Border? In Regmi G., Huettmann F. (eds) Hindu Kush-Himalaya Watersheds Downhill: Landscape Ecology and Conservation Perspectives. Springer, Cham. https://doi.org/10.1007/978-3-030-36275-1_36

R Core Team. 2020. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project. org/

Raman T.R.S., Menon R.K.G. and Sukumar R. 1996. Ecology and management of chital and blackbuck in Guindy National Park, Madras. Journal of Bombay Natural History Society, 93:178–192

Raman T.R.S. 1997. Factors influencing seasonal and monthly changes in the group size of chital or axis deer in southern India. Journal of Bioscience, 22:203–218. https:/doi.org/10.1007/BF02704733

Raman T.R.S. 2013. The chital *Axis axis* Erxleben. University Press

Ranjitsinh M.K. 1991. Deer Antelope and Bovines In: Iserial S. and Toby S. Indian Wildlife Apa publication (HK). LTD, pp 93–94.

Regmi S., Neupane B., Dhami B., Gautam D., Panthi S. and Poudel M., 2022. Niche breadth and overlap of spotted deer and domestic cattle with swamp deer in a tropical region of Nepal. Ecological Process, 11:1–10. doi.org/10.1186/s13717-022-00367-z

Sapkota S. and Chalise M.K. 2015. Population status of Spotted Deer in Baghmara Buffer Zone Community Forest, Chitwan National Park, Nepal. Nepalese Journal of Zoology, 3(1):11–16. https://www.cdztu.edu.np/njz/index.php/NJZ/article/view/65

Schaller G.B. 1998. The deer and the tiger. A study of wildlife in India. Nataraj Pubishers, Dehradun, pp 37–90

Singh B. 2016. An Assessment of Biomass and Carbon Stock in Tropical Natural Forest of Nepal (A case study of Institute of Forestry Hetauda Campus). BSc Project Paper, Tribhuvan University, Nepal.

Seidensticker J. 1976. Ungulate populations in Chitawan Valley, Nepal. Biological Conservation, 10(3):183–210. https://doi.org/10.1016/0006-3207(76)90034-3

Shaha R. and Richard M.M. 2001. Wildlife in Nepal. Nirala Publication, New Delhi, pp 76–77.

Sharatchandra H.C. and Gadgil M. 1975. A year of Bandipur. A Journal of Natural History Society 7(3):623–647

Shrestha T.K. 2003. Wildlife of Nepal. Published by Mrs. Bimala Shrestha G.P.O. Box 6133 Kathmandu, pp 223–25.

Shrestha M.K. 2004. Relative ungulate abundance in a fragmented landscape: implications for tiger conservation. the University of Minnesota.

Shrestha B.B. and Shrestha K.K. 2021. Invasions of alien plant species in Nepal: Patterns and process. Invasive Alien Species: Observations and issues from around the world, 2:168–183. https://doi.org/10.1002/9781119607045.ch20

Spillet J.J., Cohen J.E. and De R.C. 1967. The large mammal of Keoladeo Ghana Sanctuary, Rajasthan. Journal of Bombay Natural History Society, 63(3):602–607.

Subedi N., Jnawali S. R., Dhakal M., Pradhan N. M., Lamichhane B.R., Malla S. et al. 2013. Population status, structure, and distribution of the greater one-horned rhinoceros *Rhinoceros unicornis* in Nepal. Oryx, 47(3):352–360. doi:10.1017/S0030605313000562

Talan D.A., Citron D.M., Abrahamian F.M., Moran G.J. and Goldstein E.J. 1999. Bacteriologic analysis of infected dog and cat bites. New England Journal of Medicine, 340(2):85–92. Doi: 10.1056/NEJM199901143400202

Waring G.H. 1996. Preliminary study of the Behaviour and Ecology of Axis Deer on Maui, Hawaii. Department of Zoology, Southern Illinois University, Carbondale, U.S.A. Online version presented by the Hawaii Ecosystem at Risk (HEAR) project.

Wegge P., Shrestha A.K. and Moe S.R. 2006. Dry season diets of sympatric ungulates in lowland Nepal: competition and facilitation in alluvial tall grasslands. Ecological Research, 21:698–706. https://doi.org/10.1007/s11284-006-0177-7

Woodroffe R. 1999. Managing disease threats to wild mammals. Animal Conservation 2: 185–193.

White G.C. 1992. Does pellet count index white-tailed deer numbers and population change? A comment. Journal of Wildlife Management, 56:611–612. DOI 10.2307/3808879

WWF. 2007. Resources for implementing the WWF project & program standards, define threat Ranking. https://wwf.panda.org.

Westoby M. 1974. An analysis of diet selection by large generalist herbivores. American Naturalist, 108:290–304.